Numeracy and Australian workplaces: Findings and implications [1]

Gail E. FitzSimons
Monash University
<gail.fitzsimons@education.monash.edu.au>

Introduction

Numeracy in the workplace is much more complex than the simple application of mathematical knowledge and skills learned in school or vocational education. Although the knowledge and skills developed in compulsory education or in formal adult and vocational education and training (VET) courses play a foundational role, they are inevitably transformed within workplace or other contexts. This is in order to address ever-evolving problems that may require timely and creative solutions, not necessarily the neat mathematical solutions typically found in school or VET texts. It is also frequently the case that when mapped onto school mathematics curricula the actual levels appear to be relatively low at first, but these need to be understood as situated within often pressured situations in relation to time, money and safety, and almost always involve dealing with other people in the process.

In recent years the terms "mathematics" and "numeracy" have come to be used interchangeably by politicians, bureaucrats, researchers, and educators. Although an analytical distinction, based on Bernstein's conceptions of vertical and horizontal discourses, may be made (see FitzSimons, 2004; in press.), in this article I regard numeracy as a practice that draws upon and transforms mathematical knowledge to serve a particular purpose. I have recently had the privilege of visiting several workplaces under the auspices of two research grants (see Acknowledgements) in order to learn more about numeracy practices on-the-job in the Australian context.

In the first section of this article I briefly outline activity theory, which informed the methodology and analysis for both projects. I then review a selection of key findings from the international literature on mathematics/numeracy in the workplace. The third section presents findings from each project, covering a total of 21 workplace visits. This is followed by a discussion of the findings, implications for policy and practice, and a brief conclusion.

1. This article is based on a paper presented at the Adults Learning Mathematics ALM-11 conference in Gothenberg, Sweden, 29 June – 2 July 2004.

Activity theory

In their introduction to an edited book on activity theory and social practice, Hedegaard, Chaiklin, and Jensen (1999) make the following observations on its history and development. Following the work of the Russian psychologist, Lev Vygotsky, came the recognition that humans pass on tools and procedures for their use (knowledge) to the next generation. Thus, human development came to be seen as a social and cultural-historical process. In a further development, they note that:

> Leontiev conceptualised activity as a collective process, with actions as goal-oriented processes of individual subjects, and operations as psychic functions conditioned by the prevailing material conditions and available tools. … Work was taken as the prototype of activity, and other types of activity were developed through human history as derived from work. (p. 14)

Transcending the understanding of activity as solely or primarily social interaction led to "an understanding of activity as a societally and historically conditioned process" (p. 16). The authors claim that activity theory can be conceptualised as a collective process, dependent on interaction and communication, with social practice lying at the heart of the theory's conceptual structure. The researcher is necessarily part of an activity system involving participants and practices, socially, culturally, and historically situated.

Engeström (1999) describes activity theory as providing a worthy unit of analysis for enabling a theoretical account of the constitutive elements of an object-oriented, collective, and culturally mediated activity system in all its complex interactions and relationships. The minimum elements of this system include the object, subject, mediating artefacts (signs and tools), rules, community, and division of labour (Figure 1).

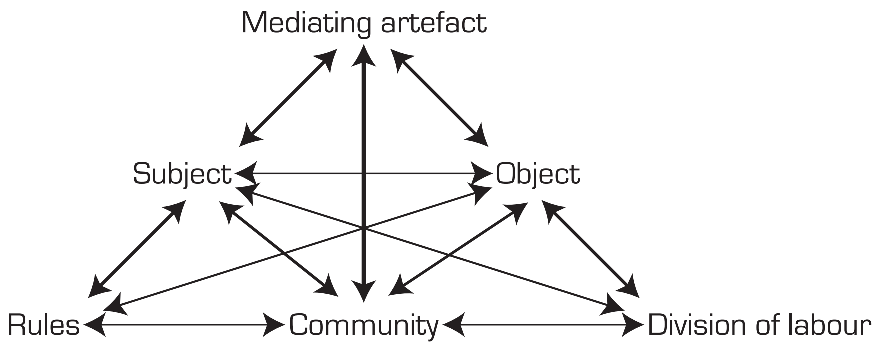

Figure 1. The basic mediational triangle expanded (after Engeström, 1987).

Kuutti (1996) elaborates on this model as follows:

> A tool can be anything used in the transformation process, including both material tools and tools for thinking. Rules cover both explicit and implicit norms, conventions, and social relations within a community. Division of labor

> refers to the explicit and implicit organisation of a community as related to the transformation process of the object into the outcome. (p. 28)

Engeström (1999, p. 9) adds that: "the internal tensions and contradictions of such a system are the motive force of change and development."

Key findings from the literature

A review of the literature (FitzSimons, in press) identified research on how mathematical/numerical skills are used in the workplace, and how they might be taught in formal educational institutions for the workplace. However, there has been little attention until now focused on how numeracy is learned in the workplace.

In their studies of three companies or organisations in each of seven key UK sectors Hoyles, Wolf, Molyneux-Hodson, and Kent (2002) concluded that:

> "mathematical literacy" is displacing basic numeracy as the minimum mathematical competency required in a large and growing number of jobs. Mathematical literacy is the term we have used to describe the application of a range of mathematical concepts integrated with a detailed understanding of the particular workplace context. There is a need to distinguish between numeracy, mathematics skill and mathematical literacy. (p. 3)

Aspects of mathematics that the Hoyles et al. (2002) study highlighted as being of significance in mathematical literacy include:

- integrated mathematics and IT skills;
- an ability to create a formula (using a spreadsheet if necessary);
- calculating and estimating (quickly and mentally);
- proportional reasoning;
- calculating and understanding percentages correctly;
- multi-step problem solving;
- a sense of complex modelling, including understanding thresholds and constraints;
- use of extrapolation;
- recognising anomalous effects and erroneous answers when monitoring systems;
- an ability to perform paper and pencil calculations and mental calculations as well as calculating correctly with a calculator;
- communicating mathematics to other users and interpreting the mathematics of other users;
- an ability to cope with the unexpected (p. 5).

Most of these skills were explicitly or implicitly part of the mathematical activities in the Australian workplaces visited for my research.

Also in the UK, Wake and Williams (2001) observed workers at eleven sites in the company of college students in order to discuss with workers the mathematical practices identified by the workers themselves. They found helpful

the notions of conflicting activity systems from cultural historical activity theory and distinct communities of practice in analysing differences between workplace and college practices that have been shaped historically by:

- different objectives of activities;
- different social structures, such as divisions of labour, rules of communication and exchange;
- different tools, instruments and signs (p. 6).

They noted the role played by an individual's mathematical knowledge, beliefs, concepts and language in playing a mediating role in their activity. Mathematical practice framed within the workplace activity system was adopted as the unit of analysis. Wake and Williams found that there were two main mechanisms that served to ensure workplace competence: the use of particular tools or artefacts to reduce the cognitive load, and the division of labour where social structures supported individuals and teams. These findings have also been supported by the research discussed below.

Methodology

There are two aims for the first, major research project, which continues until December 2006. One is to assist adult, community and vocational educators to support students and industries through identifying the kinds of numeracy used in different workplaces and in the popular media. The other is to help designers and users of online courses and CD-ROMs in adult numeracy to develop and evaluate high quality products. In order to gain further insights into adult numeracy in the Australian context, I visited nine workplaces located in suburbs around Melbourne, including a fundraising "trivial challenge" production office, a modular shed construction company, a local post office, a short-term home rental company, a graphic design company using CNC machinery, a local playgroup, a small hairdressing salon, a wholesale power tool warehouse, and an aged-care hostel.

A second, smaller project, now completed, involved investigating how mathematics/numeracy is learned on the job in the case of chemical spraying and handling. The activities of chemical preparation, application, transport, handling and storage undertaken by operative workers are high-risk activities in terms of occupational health and safety of workers, their clients and in relation to environmental damage. They place high demands on workers' numeracy and literacy skills. Twelve sites in urban and rural NSW and Victoria were visited, including parks, vineyards, orchards, plant nurseries, golf courses, and chemical warehouses.

Building on a burgeoning corpus of research into how mathematics/numeracy is used in workplaces around the world, I adapted the technique of work-shadowing used in a previous project of the Australian Association of Mathematics Teachers (AAMT), *Rich Interpretation of Using Mathematical Ideas and Techniques* (AAMT, 1997), together with social and cultural activity theory (Engeström, 1987, 1999, 2001) as a research methodology. In both projects, detailed observation of the participants undertaking

numeracy tasks occurred wherever possible. This was supplemented by semi-structured interviews with the workers and/or their immediate supervisors. The interview data and observations were analysed to identify common themes, issues, and potential strategies that could inform teaching practice. Where permission was granted, the collection of artefacts took place, including actual samples of materials used (e.g., procedures, manuals, charts); interviews were also audio-taped for further analysis.

Findings

In this section I highlight the salient findings from the nine workplace visits undertaken for the first project, and summarise their commonalities. I then conclude with a tenth set of observations drawn from the twelve visits in the second project.

1. Fundraising: Trivia challenge

This worker organised a large-scale fundraising competition which includes around 20 000 primary and secondary students in Victoria, from grades 3–10, divided into four levels. She also researched the questions herself. The major tasks included mailouts to schools, organising the question papers for individual schools at the relevant levels, arranging the finals at a major venue, purchasing prizes (token and large), and collecting the money raised. The underpinning knowledge required in order to meet the contingencies of the job, where the worker's creativity in problem solving is essential, could be covered — in theory at least — by six years of secondary mathematics. However, these skills were applied in the context of the workplace where criteria for success are very different. On a day-to-day basis the worker was largely responsible for her own work so it is imperative that she was well organised; there were always competing tasks and pre-set deadlines to meet.

2. Local post office

The major tasks observed were mail-sorting, sales of postal goods and services, other financial services (e.g., bill paying for utilities), sales of stationery, calendars, tourist items, and so forth. The characteristics of creativity and problem solving also apply to the local post office manager. One of the key issues for the manager was staying in business — that is, making enough money to cover costs (including his own salary). This needs scrupulous attention to monetary details (e.g., accurate entries on the cash register and safe, cash flows, trustworthy staff), measured creativity in seeking new items for profitable sale in a relatively small floor space, and giving customers a reliable, high level of friendly service. Calculations were of the essence in the varied planning roles. Design and storage (location) and retrieval of stock and records were also an essential ingredient. This business depended on the reliable use of statistics as a means of stock control; however, these were not witnessed in this observation.

3. Modular shed construction

This observation followed the onsite construction of a modular shed at the client's home. Although the two workers both had less than six years secondary schooling, their skills were adequate to meet the level of numeracy required. However, what is not emphasised in school mathematics is the necessity of appropriately accurate and timely readings of measurements. Checking and re-checking was essential to the whole project. Problem solving — dealing with the unexpected — was always a possibility. Sometimes it arose in order to recover from human or machine error, such as in faulty construction of the modular components delivered to the site. But a workable solution needed to be found, even if it seemed costly in terms of time and/or money. Much of the communication seemed to be tacit: well known procedures and routines had already been established between these two workers. There was limited dialogue exchanged in the confirmation of measurements or the realignment of the construction. However, these exchanges are crucial and in the case of a breakdown would need to be clearly articulated and discussed or debated. Another critical feature, already established by the workers, was the logical organisation of the project — from picking and loading the required modules onto the truck in sequence, to the final check of the completed shed.

4. Short-term home rental business

This work involved dealing with a range of activity groups (e.g., potential and actual renters, trades people, cleaners) also required mathematical thinking in order that the sequence of events for any one rental arrangement might take place as planned. Careful attention needed to be paid to optimising the tenancy rates while offering flexibility to clients. Keeping track of money — cash flow is critical — is fundamental, and requires systematic record keeping as well as highly developed planning, team-working, communication, and problem solving skills. This is in addition to the competent use of spreadsheets and other computer templates, including those of the Australian Taxation Office. These required analytical, abstract, algebraic as well as numerical thinking — especially at times of communication or technological breakdown. Efficient and effective use of the pocket calculator — especially in relation to percentages — was also essential.

5. Graphic design and use of the CNC machine

The task observed was the cutting of perspex panels for telephone boxes. The importance of accuracy of measurement and communication cannot be underestimated as mistakes are costly in terms of expensive raw materials wasted and delays in meeting customer deadlines — expensive, not only for this job, but for the company's reputation with this and other customers. Because of the creativity inevitably associated with customised work, problem solving played a critical role in setting up the process and in maintaining the correct measurements throughout the job at hand. Attending to computer-numeric-controlled (CNC) machines, which operate in three dimensions, requires the ability to think analytically and abstractly, while relating the

machine settings to the concrete numerical and measurement demands of the task. Clearly, operating the onboard controller console needed specialised training from the supplier (or more experienced workers), so familiarity with technological-mathematical equipment is required. But, unlike the school situation, every calculation or keystroke must be as accurate as is humanly possible — careless mistakes cannot be tolerated. Accuracy of measurement, and knowing the limits of measuring tools, were essential also. Both of these required that the operator have a well-developed sense of what are reasonable readings from inputs or outputs.

6. Local playgroup

There is a widespread perception that teaching is an easy job — and a very easy job to teach pre-schoolers in particular. The opposite is the case. There was a significant requirement for forward planning of activities and availability of the materials required to support the children's activities. Constant monitoring of children and communication between staff was essential for the smooth flow of the program, as well as for safety reasons. The teacher-training side of early childhood education is also becoming increasingly important — not least in mathematics education. The preparation of new workers in this industry now requires a greater depth of knowledge and understanding of the mathematical principles and their associated pedagogies. There are also serious accountability requirements as regulation by the Department of Human Services continues to tighten. Financial viability of the program is always a pressure, so that the teacher/coordinator needed to work within her budget.

7. Local hair salon

In this workplace, knowledge of client needs and preferences in style and colour needs to be kept up to date on computerised records, with new requests accommodated at each visit. This requires the ability to understand the logic of the database system in order to enter and/or interpret data. Computer use requires a knowledge of prices to enable estimation of reasonableness; also ability to problem solve. Given the importance of stock control and accurate record keeping for economic viability and financial accountability for taxation purposes, there are serious requirements for mathematical skills and knowledge in the daily practice of a salon such as this. This is in addition to the "invisible" skills of design and location, which encompass not only the styling and colouring of hair, but also the layout of the salon (front and back of house). Measurement skills were most obvious in the preparation for hair colouring — although the level of accuracy was mostly determined by past experience. In an industry such as this, the ability to communicate is of the essence, and this incorporates mathematical thinking even though this may be largely invisible most of the time.

8. Wholesale warehouse

This company sold a range of power tools and cutting machines (large and small) to hardware retailers. Record-keeping and stock control needed to be

accurate and up-to-date in order to ensure the smooth flow of dispatches. Technologisation of both packaging and organisation is rapidly occurring, and workers need to keep abreast of the developments, adapting to these new technologies of management, equipment, and record keeping. There was a logical flow of tasks to be executed in an optimal way, keeping in mind the constraints of carriers' pick-up times and capacities. Computer use requires knowledge of spreadsheets, specialised data processing, and labelling. Choice of packaging materials and composition of consignment is context dependent and related to the nature of the sales items (e.g., shape, dimensions, value). Clear and accurate communication was of the essence, and was generally overtly mathematical in nature: identification codes, locations, measurements, costs and times, for example.

9. Aged-care hostel

Although the advent of pre-packed drugs appears to have removed the most obvious indicator of mathematics used on the job for personal care workers, there are less visible numeracies at work. For example, new ways of working include:

1. Quality auditing that has changed the way practices are undertaken; there are flow charts for every action.
2. Changes in legislation which have introduced the need for formalised training in areas such as privacy and dignity; also that photographs be attached to residents' records and medication lists for checking when medication is administered.
3. Emergency colour codes that need to be learned and responded to automatically.
4. In this hostel, a new fire detection system has been installed, with a complex diagram that needs to be interpreted in order to locate the source of any fire as a matter of urgency.

The small size of this hostel required that personal care workers may also be responsible for budgeting for food orders while maintaining good quality meals. The daily routines included medication rounds before and after meals, showering and dressing residents who required assistance, organising the totality of activities around mealtimes (e.g., setting tables, organising seating, cleaning up), as well as general cleaning and laundry. The particular worker observed also completed the bookwork for the Quality Audit. Communication was of the essence:

(a) with residents about their immediate needs;
(b) with residents' families about their needs, monthly or as required;
(c) with visiting doctors about residents' healthcare needs;
(d) with the local pharmacy about supply (and sometimes clarification) of necessary drugs, etc.;
(e) with other personal care workers about residents and daily routines; and
(f) with management about changes to routines, rosters, critical incidents, and includes completed time sheets.

Summary

Most, if not all, of the Mayer (1992) Key Competencies were observed in all nine workplaces:

(a) collecting, analysing and organising information;
(b) communicating ideas and information;
(c) planning and organising activities;
(d) working with others and in teams;
(e) using mathematical ideas and techniques;
(f) solving problems; and
(g) using technology.

Similarly, most if not all of Bishop's (1988) "pan-cultural" activities were also observed: counting, designing, explaining, locating, measuring, and playing.

Underlying mathematical knowledge and skills included algebraic thinking (for spreadsheets), calculations (with and without a calculator) and associated relevant estimation skills, geometric thinking, logic, measurement, and the accurate storage, retrieval, display, and interpretation of data. Clear communications with other stakeholders and creative problem solving were essential. Other mathematics-related competences for those in positions of responsibility included high level skills in forward planning and organisation, as well as the ability to keep the operation financially viable and to meet other legal requirements (e.g., accurate and timely record-keeping) for accountability purposes.

10. Chemical spraying and handling

These tasks were undertaken by workers as just one aspect of a range of duties, and ranged from small-scale weed spraying from a backpack to broad acre spraying drawn by a tractor. The following were identified as the underlying mathematics concepts in chemical spraying and handling: addition, subtraction, multiplication and division of whole numbers and decimals; ratio and proportion; measurement: length, area, volume, capacity, mass [usually metric]; estimation; and approximation. The following were identified as processes used by workers to undertake these calculations: estimation, pencil and paper methods, use of basic four-function calculator; verbal or written communication with other workers; consultation with prescriptive calculations sheets and with historical records; completion of up-to-date records of chemicals used and their amounts; and consideration of other contextual factors, e.g., date/time; block area; crop; crop stage; weed/pest/disease targeted; chemical group; rate/ha; litre spray applied; method of application; temperature; wind speed; wind direction; rainfall; and humidity.

Most of these basic calculations are taught initially in school prior to the post-compulsory years. In the case of chemical spraying, most, if not all, of the workers have the Farm Chemical Users Certificate, or equivalent, and the relevant calculations are revised and practised here, in (semi-) contextualised settings. That is, the students get to observe and experience actual measurement skills, but what they lack are the ongoing records of any one particular site that provide a deep sense of meaningfulness to their calculations. For the other workplace observations, it seems that most relevant learning is done in

the contextualised workplace, through observation, reflection, and creative adaptation to the artefacts and problems or goals at hand. However, these need to be supported by a firm foundation in school mathematics — beyond minimal grades for certification — together with a determination to make sense of available data (present and historic), and a positive, creative approach to problem solving, especially in workplaces where timely and cost-efficient resolutions are imperative.

In the chemical spraying workplace, calculations are always checked in some form by another person, whether the supervisor or the tractor driver, for example. Previous experience and historical data play a big role in determining reasonableness of answers. It also determines whether and how to approximate answers. Most importantly, the learning in the workplace varies from school mathematics education in that workers are always reminded to check their calculations for reasonableness, to ask repeatedly if they are not sure, and to consider their own and others' personal safety.

Discussion of the findings

In the first nine workplaces, apart from specialised computer training, most learning seemed to be "on-the-job". However, this ability to learn requires a strong general mathematics education, in order that the workers can quickly adapt to the idiosyncrasies of their workplace contexts. Logical thinking and problem solving are examples of mathematical competences that can develop over the compulsory years and be refined by further formal education in numeracy as well as on-the-job. The ability to communicate is of the essence, and this incorporates mathematical understandings even though they may be largely invisible most of the time. Accordingly, the development of authentic communication skills should form an integral part of any mathematics or vocational numeracy education.

The numeracy task of preparing and applying chemicals requires that the person responsible must take into account a complex set of variables. The notion of direct transferability of the mathematical skills is problematic. Numeracy in chemical spraying and handling is always a social-historical and cultural practice. Estimation is always absolutely necessary, based on prior experience of the kind of spraying needed, or even of just sensible results for the novice. Common sense is of the essence. Judgements are needed as to when it is appropriate to approximate the chemical mixture and when it is not, and how this approximation may be usefully made. It is never acceptable to make a mistake in the actual process. It may threaten public safety and also the livelihoods of the operators and their managers. All calculations must be double-checked, and asking questions where any doubt exists is strongly and repeatedly encouraged. Consistent information provides the bedrock and starting point for workers, for example, the calculations are always determined by the units of the equipment. Confidence in undertaking the numeracy tasks comes from several sources, including the support of "expert" knowledge from the managers within the workplaces as well as the Internet.

Team and group work is fostered as part of workplace practice. Artefacts are used as resources to aid in formal calculations, or in other situations requiring assessment and evaluation.

The findings from both projects support the messages (e.g., Hoyles et al., 2002; Wake & Williams, 2001) from the international literature on mathematics/numeracy in the workplace. For example, mathematical elements in workplaces are subsumed under workplace routines, structured by mediating artefacts (e.g., tools and equipment, calibration templates, record sheets), and highly context-dependent. In other words, the priority is to get the job done as efficiently as possible — not to practise and refine mathematical skills. Although solutions to calculations and eventual measurements and operations for chemical spraying must necessarily be error-free, unlike school the actual methods used allow some discretion with respect to the manner in which these are achieved and, more importantly, they involve the collaboration with or validation by at least one other person with experience of the task as well as historical records. Unlike school, the results really matter in terms of public and personal safety, environmental protection, and maintaining one's job. Somewhat paradoxically, the mathematical correctness or precision may be negotiable, according to the task at hand; for example, rounding 447 litres to 450 litres, or judging 15 ml to be about halfway between 10 ml and 20 ml on a graduated scale, whereas, in other contexts, scientific balances are used for weighing milligrams.

In light of the findings, the definition of numerate behaviour by Coben (2003) seems most appropriate in the context of numeracy in the workplace:

> To be numerate means to be competent, confident, and comfortable with one's judgements on whether to use mathematics in a particular situation and if so, what mathematics to use, how to do it, what degree of accuracy is appropriate, and what the answer means in relation to the context. (p. 10)

Implications for policy/practice

Heeding one worker's comment that, "School mathematics and practical mathematics are entirely different," suggests that it may be possible to substantially revise school and vocational education and training (VET) mathematics curricula and pedagogy in order to allow students to develop more useful skills for work and other life situations in which they find themselves, now and in the future. But this does not mean a reduction to the lowest common denominator of visible[2] numeracy skills: rather an increased recognition of the complexities of the workplace and the interconnectedness of tasks. Apart from specialised computer training, most workplace learning seems to be "on-the-job". However, this ability to learn requires a strong general mathematics education — one which aims at developing deep understandings of concepts such as number and measurement (together with their

2. Kanes (2003) describes the theme of visibility as being about how numerical knowledge is formalised and controlled.

fundamental inter-relationships), statistics and space, in association with practical modelling and problem solving — in order that the workers can transform their existing mathematical (and other) knowledge and skills to adapt to the idiosyncrasies of their particular workplace contexts.

The findings from both projects suggest that new workers need to learn exactly how particular processes operate. As they become experienced, they may be enabled to participate fully in the social, cultural, and technological processes of the workplace, possibly even contributing to new knowledge as conditions change. Logical thinking and problem solving are examples of mathematical competences that can develop over the compulsory years and be refined by further formal education in numeracy as well as on-the-job participation. Joint project work can support the development of communication skills, planning, and teamwork.

Along the same lines, the findings suggest that it is essential that formal vocational numeracy courses attend to the spectrum of mathematical activities highlighted above; that is, to include a broad range of concepts beyond simplistic rational number and measurement skills. It is commonplace that pedagogy should attempt to contextualise the skills and knowledge required, but this could be supported by addressing each of the Mayer Key Competencies (separately or in concert) in order to attempt to model workplace activities in a realistic manner. However, pseudo-contextualisations need to be avoided at all costs. Not only are they demeaning to adults and youths, they fail to prepare them for participation in the varied discourses of the workplace (FitzSimons, 2002).

Learners who have been away from formal education for some time and others who did not succeed in the school environment may need some assistance in learning to learn. Most importantly, they need to have their existing skills and knowledge acknowledged, and built upon. They need to become reflective on their own practice and their own learning, able to use those reflections to inform practice, and understanding that learning is ongoing and that practice is always developing. They need to learn thinking skills to manage information, pose useful questions, and to solve problems, especially in co-operation with others. They need to learn how to be in control of their own learning, rather than dependent on others.

Questions arise as to how competently VET students would be taught by teachers or trainers with little or no background in mathematics education, particularly in relation to adult learners who have been away from formal education for some time or to early school leavers. In any case, holistic rather than atomistic teaching methods would enhance the capacity of the learners to accommodate the complexity of demands they may face on-the-job. Teachers and trainers need to be aware that numeracy is not just "basic maths" but a complex set of skills and knowledge drawn upon in often ill-defined situations for ever-evolving problems. There is an urgent need for specialised initial preparation of and ongoing professional development for teachers and trainers involved in adult numeracy teaching in the VET sector. Similarly, research is also needed for the further development of vocational teacher/trainer education in relation to numeracy, for and in the workplace.

Conclusion

This article has given an account of workplace observations intended to illuminate the mathematical practices utilised by workers in their everyday practices. Activity theory was used as a theoretical framework in order to go beyond essentialist accounts common in the past (see FitzSimons, 2002). Any workplace activity is necessarily socially, culturally, and historically located. Numeracy education for the workplace must also take into account the complex issues that surround apparently simple calculations, and the importance of social, cultural, and historical contexts. The challenge for the future is to adequately prepare numerate citizens for whatever life and work circumstances they confront.

In terms of activity theory, teaching and "doing" mathematics in school do not reflect the activity of being a mathematician; neither can vocational mathematics or numeracy teaching in institutional settings reflect the complex activity of the workplace or other lifeworld setting, where the numeracy skills are merely tools to be developed pragmatically in order that the task may be achieved as efficiently as possible. Numeracy education in the workplace requires a fundamentally different curriculum and pedagogy from that of school mathematics, yet encompassing underpinning mathematical knowledge and skills in ways that enable the generation of "new" knowledge in order to solve problems that cannot always be known in advance. These ideas are elaborated in FitzSimons and Wedege (2004).

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References

Australian Association of Mathematics Teachers Inc. (1997). *Final Report of the Rich Interpretation of Using Mathematical Ideas and Techniques Key Competency Project.* Adelaide: Author.

Bishop, A. J. (1988). *Mathematical Enculturation: A Cultural Perspective on Mathematics Education.* Dordrecht: Kluwer Academic Publishers.

Coben, D. (with Colwell, D., Macrae, S., Boaler, J., Brown, M., & Rhodes, V.) (2003). *Adult Numeracy: Review of Research and Related Literature.* London: National Research and Development Centre for Adult Literacy and Numeracy. [Available as PDF from www.nrdc.org.uk]

Engeström, Y. (1987). *Learning by Expanding: An Activity-Theoretical Approach to Developmental Research.* Helsinki: Orienta-Konsultit. Retrieved 20 February 2003, from: http://lchc.ucsd.edu/MCA/Paper/Engeström/expanding/toc.htm.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R.-L. Punamäki (Eds), *Perspectives on Activity Theory* (pp. 1–16). Cambridge: Cambridge University Press.

Engeström, Y. (2001). Expansive learning at work: Toward an activity-theoretical reconceptualization. *Journal of Education and Work, 14*(1), 133–156.

FitzSimons, G. E. (2002). *What Counts as Mathematics? Technologies of Power in Adult and Vocational Education.* Dordrecht: Kluwer Academic Publishers.

FitzSimons, G. E. (2004). *An overview of adult and lifelong mathematics education.* Keynote presentation at Topic Study Group 6, 10th International Congress on Mathematics Education [ICME-10]. [Available from the World Wide Web: http://www.icme-10.dk]

FitzSimons, G. E. (in press). *Adult Numeracy and Workplace Learning.* Adelaide: National Centre for Vocational Education Research.

FitzSimons, G. E. & Wedege, T. (2004). Developing numeracy in the workplace: The context of chemical spraying. In *Workplace Learning — From the Learner's Perspective* (Conference proceedings). Retrieved 25 November 2004, from: http://wl-conference.2004.lld.dk/abstractspapers.html]

Hedegaard, M., Chaiklin, S. & Jensen, U. J. (1999). Activity theory and social practice: An introduction. In S. Chaiklin, M. Hedegaard, & U. J. Jensen (Eds), *Activity Theory and Social Practice* (pp. 12–30). Aarhus: Aarhus University Press.

Hoyles, C., Wolf, A., Molyneux-Hodson, S. & Kent, P. (2002). *Mathematical Skills in the Workplace. Final Report to the Science, Technology and Mathematics Council.* Foreword and executive summary. London: Institute of Education, University of London: Science, Technology and Mathematics Council. [Retrieved 27 January 2004, from: http://www.basic-skills-observatory.co.uk/uploads/doc_uploads/522.pdf]

Kanes, C. (2003). Developing numeracy. In J. Stevenson (Ed.), *Developing Vocational Expertise: Principles and Issues in Vocational Education* (pp. 81–109). Sydney: Allen & Unwin.

Kuutti, K. (1996). Activity theory as a potential framework for human-computer interaction research. In B. A. Nardi (Ed.), *Context and Consciousness: Activity Theory and Human-Computer Interaction* (pp. 17–44). Cambridge, MA: The MIT Press.

Mayer, E. (Chair). (1992). *Report of the Committee to Advise the Australian Education Council and Ministers of Vocational Education, Employment and Training on Employment-related Key Competencies for Post-Compulsory Education and Training.* Melbourne: Australian Education Council and Ministers of Vocational Education, Employment and Training.

Wake, G., & Williams, J. (2001). *Using College Mathematics in Understanding Workplace Practice: Summative Report of Research Project Funded by the Leverhulme Trust.* Manchester: The University of Manchester. [Available as PDF from http://www.education.man.ac.uk/lta/publications/index.shtml]